DOCUMENT RESUME

ED 051 321 UD 011 544

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TITLE Malnutrition and Learning.
INSTITUTION Michigan State Univ., East Lansing. Center for Urban Affairs.
REPORT NO RR-5
PUB DATE [71]
NOTE 12p.

EDRS PRICE EDRS Price MF-$0.65 HC-$3.29
DESCRIPTORS Breakfast Programs, Early Experience, *Educational Problems, Food Standards, Health Needs, *Hunger, Individual Development, Learning Difficulties, *Learning Disabilities, Lunch Programs, Neurologically Handicapped, *Nutrition, Perceptually Handicapped, *Prenatal Influences, Socioeconomic Status

ABSTRACT

The characteristics of malnourished children bear a striking resemblance to a number of the known characteristics of "disadvantaged children," e.g. apathy, irritability, sickliness, and a reduced attention span. The combination of malnutrition and the other negative effects of poverty perpetuates a cycle of illness, educational failure, and more poverty. If the aim of compensatory education is to break this cycle, then it is imperative that social scientists and educators become aware of the negative impact of malnutrition on the development of the child. Perhaps most specific to education is the demonstration of delayed neurointegrative development in children who have grown poorly because of malnutrition. Inadequacies of intersensory development can place the child at the risk of failing to establish an ordinary normal background of conditioning in his pre-school years, and at the risk of failing to profit from educational experience in the school years. Measures to insure the "equal creation" of each child are urgently needed. (Author/JM)

ED051321

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MALNUTRITION AND LEARNING*
Research Report No. 5

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*This paper has appeared in the following:

Clasen, R.E., Programmed Child Development Course, University of Wisconsin, Racine, Wisconsin.
Grambs, J.D., Education in the World Today, Addison-Wesley, Palo Alto, 1971.
Heidenreich, R.R., Urban Education.
Lindgren, H.C., Readings in Educational Psychology, John Wiley, New York.

The article is also due to appear in:

Readings in Health Education -- in process of being compiled into a book by Brent Q. Hafe, Ph.D., Department of Health Science, Brigham Young University, Provo, Utah, 84601.

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UD011544

To paraphrase Hemingway's dialogue with Fitzgerald, the poor are different from us - they have less money.[1] They also have children who in general do poorly in school and on tests of intelligence. In part this is due to social and psychological factors, and such children have been called "culturally disadvantaged" or "socially deprived." But the poor also have a higher infant mortality rate, a higher incidence of infectious and chronic diseases, and a greater number of premature and low birth-weight infants.[2] All of these factors are in turn related to the disproportionate number of poor children who are mentally retarded.[3]

Data currently being developed indicate that malnutrition is the common denominator of all these ills. The characteristics of malnourished children bear a striking resemblance to a number of the known characteristics of "disadvantaged children, e.g., apathy, irritability, sickliness, and a reduced attention span.

The combination of malnutrition and the other negative effects of poverty perpetuates a cycle of illness, educational failure, and more poverty. If the aim of compensatory education is to break this cycle, then it is imperative that social scientists and educators become aware of the negative impact of malnutrition on the development of the child. The purpose of this paper is to present some of the evidence, based on animal and human studies, linking malnutrition to the growth of the brain, the performance of various intellectual functions, and other developmental variables related to learning.

[1]Fitzgerald: "The rich are different from you and me." Hemingway: "Yeah, they have more money."
[2]C. U. Lowe, "Child Health and Public Policy." *Grover Powers Memorial Lecture*. New Haven, Conn.: Yale University Press, 1969, p. 16.
[3]A. Kushlick. "Assessing the Size of the Problem of Subnormality." in J. E. Meade and A. S. Parkes (eds.), *Genetic and Environmental Factors in Human Ability*. New York: Plenum Press, 1966, p. 121.

Brain Development and Function

Numerous investigations[4] of the effect of malnutrition on the weight of the brain of the rat and of the pig have reported similar results: Undernutrition from birth to 21 days produces a persistent and permanent reduction in brain weight. The earlier the malnutrition the more severe is the effect and the less likely is recovery. Undernutrition also results in specific degeneration within brain cells; again, the earlier the restriction, the more severe the damage.

Results of studies of malnutrition on cellular growth patterns indicate that early restriction of food interferes with cell division and that the animal is left with a deficit in the *number* of cells in all organs, even after adequate refeeding. Late malnutrition results in a decrease in cell size, with recovery on refeeding. While the extent and duration of undernutrition and rehabilitation are important, the age at which the undernutrition occurs appears to be the crucial variable.

There is also evidence of what may be termed "double deprivation." The offspring of rats who are malnourished during pregnancy show a reduced number of brain cells. Even if they are fed normally after birth they do not recover and are left with a permanent deficit in brain cell number. The effects of postnatal malnutrition on animals who have already suffered prenatal malnutrition are more marked than effects of either prenatal or postnatal deprivation separately. It would seem that prenatal malnutrition made these animals more susceptible to postnatal undernutrition.

In general, the animal studies have shown that during the preweaning period in the rat an enormous amount of chemical change is taking place within the brain and that this is the time when the brain is most sensitive to the

[4]M. Winick, "Malnutrition and Brain Development," *Journal of Pediatrics*, May, 1969, p. 667.

detrimental effects of undernutrition. The brain of the mature rat who was malnourished during this period is not only physically smaller but shows degenerate cell changes. If the deprivation occurs early in infancy, these changes are irreversible, while the effects of later deprivation may be reversed through proper feeding.

Behavioral changes were also evident as the result of malnutrition. After only four days on a restricted diet, rats began to develop spasmodic trembling of the head and forepaws, pigs exhibited various motor abnormalities, and puppies became hyperirritable.[5] A decrease in exploratory behavior was suffered by rats who were malnourished during the preweaning period.[6]

One of the most intriguing findings in this area is that poor nutrition of the infant female may affect the development of her offspring many years later.[5] On the basis of a number of studies, Cowley[7] suggests that the nutritional history of previous generations must be taken into consideration when studying the present generation. Whether the poorer test behavior of successive generations of animals fed deficient diets was due to enhanced nutritional deficiency in the young or to differences in the behavior of malnourished mothers toward their offspring is yet to be determined.

Available evidence from human studies reinforces the findings of experiments with animals and suggests that early infancy is a critical period for the development of the brain. This is also the time when the brain is extremely vulnerable to the effects of malnutrition.[8] Since direct measurement of brain growth in humans is not possible with living children,

[5]B. S. Platt, C. R. C. Herald, and R. J. C. Stewart, "Experimental Protein-Calorie Deficiency," in H. N. Munro and J. B. Allison (eds.), *Mammalian Protein Metabolism*, Vol. 2. New York: Academic Press, Chap. 21.
[6]R. H. Barnes, A. U. Moore, I. M. Read, and W. G. Pond, "Effect of Food Deprivation on Behavioral Patterns," in N. S. Scrimshaw and J. E. Gordon (eds.), *Malnutrition, Learning, and Behavior*, Cambridge, Mass.: MIT Press, 1968, p. 168.
[7]J. J. Cowley, "Time, Place, and Nutrition: Some Observations from Animal Studies," in Scrimshaw and Gordon, *op cit.*, p. 218.
[8]M. Winick, *op. cit.*

an indirect measure which has been widely employed is the rate of increase in head circumference. Malnutrition, especially during the first year of life, will curtail the normal rate of increase in head circumference.[9] This reduced head circumference of malnourished children, during the first six months of life, according to Winick,[10] accurately reflects the reduced number of cells present in their brains. Monckeberg[11] has demonstrated that the brain of a severely malnourished child may be even smaller than the head circumference would indicate. He has developed a "trans-illumination" test which reveals the presence of spinal fluid in the skull. The test is conducted by focusing a thousand-watt light on top of the skull. As the light is diffused, the surrounding area glows. In normal children, this area is very small, but in the affected children the entire brain case glows, from the forehead to the back of the head. A fluid, similar to spinal fluid, fills the cavity between the brain and the skull.

What is the relationship of these changes in brain development to behavior and intelligence?

The children in the Monckeberg study were restored to physical health, but follow-up intelligence tests showed that they achieved lower scores than children who had not suffered from malnutrition. Their greatest deficit was in the area of language development. Similarly, the malnourished children studied by Stoch and Smythe[12] who exhibited reduced head circumference had lower I.Q.'s even after long-term follow-up.

[9]M. B. Stoch and S. M. Smythe, "Undernutrition During Infancy, and Subsequent Brain Growth and Intellectual Development," in Scrimshaw and Gordon, *op cit.*, p. 269.
[10]M. Winick and P. Rosso, "Head Circumference and Cellular Growth of the Brain in Normal and Marasmic Children," *Journal of Pediatrics*, May, 1969, p. 774.
[11]F. Monckeberg, "Nutrition and Mental Development," Paper presented at the Conference on Nutrition and Human Development, East Lansing, Michigan, 1969.
[12]Stoch and Smythe, *op. cit.*

Using a wide battery of tests, Klein and Gilbert[13] studied the performance of malnourished and normally nourished children from the same social class. On tests where the test stimulus was only available for a short period of time, the malnourished children performed less well than the normally nourished. There was no difference in performance when the duration of the test stimulus was not controlled. The deficit which the malnourished children exhibited seems to involve speed of perception or of information processing and impairment of short-term memory.

A series of studies by Cravioto and his associates[14] in Mexico and Guatemala has shown that performance of children on psychological tests was related to nutritional factors, not to differences in personal hygiene, housing, cash income, or other social and economic variables. The performance of both pre-school and school children in Mexico on the Terman-Merrill, Gesell, and Goodenough draw-a-man tests was positively correlated with body weights and body heights. A similar positive relationship between size and performance was found in Guatemala. The tests used in this study provided measures of visual, haptic, and kinesthetic sensory integration. Children exposed to perceptual defects as well as smaller body size. The earlier the malnutrition, the more profound the psychological retardation. The most severe retardation occurred in children admitted to the hospital under six months of age and did not improve on serial testing even after 220 days of treatment. Admitted later, children with the same socioeconomic background and the same severe malnutrition but a different time of onset did recover after prolonged rehabilitation.

[13]R. E. Klein and O. Gilbert, "Malnutrition and Intellectual Development." Paper presented at the XI Inter-American Congress of Psychology. Mexico City, Mexico, 1967.

[14]J. Cravioto, E. R., DeLicardie and H. G. Birch, "Nutrition, Growth, and Neurointegrative Development: An Experimental and Ecologic Study," *Pediatrics Supplement*, Vol. 38, No. 2, Part II, 1966, p. 319.

Cravioto *et al.* conclude that nutritional inadequacy may interfere with both the staging and the timing of development of the brain and of behavior. Their demonstration of delayed neurointegrative development in children who have grown poorly because of malnutrition has important implications for more complex psychological functioning: "Evidence already exists that the lag in the development of certain varieties of intersensory integration has a high correlation with backwardness in learning to read. Studies of reading disability in British (and) American school children have shown that backwardness in reading is strongly associated with inadequacy in auditory-visual integration. Skill in visual-kinesthetic integration is found to be highly and significantly correlated with design copying in normal children. If it is recognized that such visual-motor control is essential in learning to write, it becomes apparent that inadequacy of intersensory organization can interfere with a second primary educational skill - learning to write.

Thus, inadequacies of intersensory development can place the child at rick of failing to establish an ordinary normal background of conditioning in his pre-school years and at the risk of failing to profit from educational experience in the school years."

In addition to the negative impact of malnutrition on the growth rates and intersensory development of children, Cravioto found a relationship between these aspects of development and infection. Eichenwald[15] has shown that certain infections in malnourished children may produce a severe and prolonged hypoglycemia, a condition which can by itself cause brain damage. In addition, various biochemical defects of children with malnutrition are accentuated by infection. There is the further possibility that many infectious diseases,

[15]H. F. Eichenwald and P. C. Fry, "Nutrition and Learning," *Science*, February, 1969, p. 664.

or the treatment of these diseases, result in damage to the nervous system that is not necessarily evident during the acute stage of the illness. Eichewald concludes by saying: "Infection and malnutrition thus act synergistically to produce a chronically and recurrently sick child less likely to react to sensory stimuli from his already inadequate social environment."

Effects of Prenatal Nutrition

Further evidence of the interrelationship of poverty, malnutrition, illness, and the development of the child is found in a study which identifies undernutrition of poor urban mothers as the cause of the low birth weight of their offspring.[16] Since it has been found that both low birth weight and a high infant mortality rate are more common in poor families, the finding that undernutrition appears to be the cause of prenatal growth retardation is an important one. In addition to being 15 percent smaller in body weight, the infants from poor families had multiple evidences, in terms of the relative weight of such organs as the thymus, spleen, liver, etc., of prenatal undernutrition. The biggest difference found was in the relative weight of the thymus. The offspring of non-poor families had a mean thymus weight which was 104 percent of the "normal" weight, while the poor infants had a mean thymus weight of only 66 percent of "normal." While the function of the thymus[17] is not yet completely understood, there is increasing evidence that it is involved in both growth and immunological functions.

Evidence of the nutrition of the mother is one of the important variables related to the intellectual performance of the child has also been increasing. Children whose mothers received a vitamin supplement during pregnancy had

[16]R. L. Naeye, M. M. Diener, W. S. Bellinger, and W. A. Blane, "Urban Poverty Effects of Prenatal Nutrition," *Science*, November, 1969, p. 1026.
[17]V. Defendi and D. Metcalf, *The Thymus*. Philadelphia: Wistar Institute Press, 1964.

significantly higher I.Q.'s at three and four years of age than did children whose mothers received placebos.[18] Erickson, [19] on the basis of a later study, also found that "when vitamin supplementation was given to pregnant and lactating women with poor nutritional environment, the offspring at four years of age had an average I.Q. score eight points greater than the average score of the children of mothers given a placebo over the same period." Kennedy's study of prenatal nutrition on the general measure of intellectual and physical health yielded similar results.[20]

Nutritional Therapy and I.Q.

A number of other studies have been done which have also demonstrated that nutritional therapy of the child may have a beneficial effect on intellectual performance. Kugelmass *et al.*[21] demonstrated an increase in I.Q. of both retarded and mentally normal children as a result of prolonged nutritional rehabilitation. The children, ranging in age from 2 to 10, were divided into two groups, those who were malnourished and those who were well-nourished. Each of these groups included retarded and normal children. The *malnourished* retarded children showed a gain of 10 points and the normal children, one of 18 points after a period of dietary improvement. In contrast, there was relatively little change in the scores of the *well-nourished* retarded and normal children.

[18] R. F. Harrell, E. R. Woodyard, and A. J. Gates, "Influence of Vitamin Supplementation of Diets of Pregnant and Lactating Women on the Intelligence of their Offspring." *Metabolism*, September, 1956, p. 555.
[19] M. T. Erickson, "Intelligence: Prenatal and Preconception Environmental Influences," *Science*, September, 1967, p. 1210.
[20] W. A. Kennedy, addendum to "Intelligence: Prenatal and Preconception Environmental Influences," *Science*, September, 1967, p. 1210.
[21] I. N. Kugelmass, L. E. Poull, and E. L. Samuel, "Nutritional Improvement of Child Mentality," *American Journal of Medical Science*, November, 1944, p. 631.

Harrell[22] found that in closely matched groups of presumably normal orphanage children, the double-blind daily administration of a placebo versus a 2 mg thiamine tablet for one year produced a superior mental response in the vitamin group. Muecher and Guenwalt[23] demonstrated that improvement of intellectual functions can be extended even into the late teens. Students who received vitamin and mineral supplements showed a significant improvement in the performance of mental arithmetic as compared to students receiving a placebo.

Coursin[24] has shown that deficiencies in the B-complex vitamins and in vitamin C can produce abnormalities of nerve cell metabolism and function and can impair mental development. Vitamin therapy has effected improved mental functioning with such children.

Motivation and Personality Changes

In addition to the relatively direct effects of malnutrition and illness on learning, there are many more indirect effects which are difficult to isolate. It has often been observed that the malnourished child is more likely to be apathetic, irritable, and lack a long attention span. "One of the first effects of malnutrition is a reduction of the child's responsiveness to stimulation and the emergence of various degrees of apathy. Apathetic behavior in its turn can function to reduce the value of the child as a stimulus and to diminish the adults' responsiveness to him. Thus apathy can provoke apathy and so contribute to a cumulative pattern of reduced adult-child interaction. If

[22] R. F. Harrell, "Mental Response to Added Thiamine," *Journal of Nutrition*, March, 1946, p. 283.
[23] H. Muecher and G. Gruenwald, "Pharmacologic Stimulation of Arithmetic Performance and Graphomotor Expansion," *Perceptual and Motor Skills*, August-December, 1962, p. 101.
[24] D. B. Coursin, "Effects on Central Nervous System Function," *Nutrition Review*, March, 1965, p. 65.

this occurs it can have consequences for stimulation, for learning, for maturation, and for interpersonal relations, the end result being significant backwardness in the performance of later more complex learning tasks.[25]

There is an increasing amount of evidence which indicates that severe malnutrition of young infants produces significant brain damage. Mild malnutrition occurring prenatally or in the first six months of life may also produce negative effects on learning and growth. This is the beginning of a vicious cycle of illness, slow development of intellectual functions, and inhibited growth which in turn prevent the individual from being able to protect his own children from the ravages of poverty. The *time* at which malnutrition occurs is crucial to the further development of the child. The earlier the malnutrition the more severe the effects and the more likely that they cannot be reversed. There is evidence that if malnutrition occurs after a certain age its effects on learning are reversible. Though the exact nature of the timing is yet to be worked out, it is becoming clear that the prenatal period and the first six months of life are critical.

In view of these findings, what can be done to insure that every child in America has the same chance of being "created equal"? Obviously, those most at risk are pregnant women and infants. The school would hardly seem to be the ideal setting for reaching this part of the population. Consider, however, the enormous percentage of first babies born to teen-age mothers. If the vital importance of prenatal and early infant nutrition could be conveyed to these girls, not only would they spare themselves many of the complications

[25]J. Cravioto and B. Robles, "Evaluation of Adaptive and Motor Behavior During Rehabilitation from Kwashiorkor," *American Journal of Orthopsychiatry*, April, 1965, p. 449.

of pregnancy and delivery[26,27] but they would also ensure the healthy development of their babies.

In addition, there are the benefits, both short- and long-range, of providing all school children, and pre-school children when possible, with high quality breakfasts and lunches. There is evidence that malnutrition is increasing regardless of social class,[28] and not only poor children would benefit from these meals. Finally, there is the effort which as citizens and consumers we can make to insure that key staple foods are upgraded by enrichment, that the nutritional knowledge of those purchasing food and planning meals is imporved, and *that food is made more readily available to those in real need.*

The most noxious of poverty's effects is malnutrition and the most important of the causes of malnutrition is poverty. Until this cycle is broken, the success of all our other efforts, such as compensatory education or remedial education will be limited if not doomed to failure. As Margaret Mead has so eloquently put it, "Human beings have maintained their dignity in incredibly bad conditions of housing and clothing, emerged triumphant from huts and log cabins, gone from ill-shod, childhood to Wall Street or the Kremlin . . . but food affects not only man's dignity but the capacity of children to reach their full potential, and the capactiy of adults to act from day to day. . . . It is true that the starving adult, his efficiency enormously impaired by lack of food, may usually be brought back again to his previous state of effiency. But this is not true of children. What they lose is lost for good . . . deprivation during prenatal and postnatal growth can never be made up."[29]

[26]R. H. J. Hamin, "The Prevention of Eclampsia and Pre-Eclampsia," *Lancet*, January, 1952, p. 64.
[27]T. H. Brewer, *Metabolic Toxemia of Late Pregnancy: A Disease of Malnutrition.* Springfield, Ill.: Charles C. Thomas, 1966.
[28]N. Kotz, *Let Them Eat Promises.* Englewood Cliffs, N.J.: Prentice-Hall, 1969.
[29]M. Mead, "The Changing Significance of Food," *American Scientist*, March-April, 1970, p. 176.